Response of CMS Hadron Calorimeter to Electron Beams

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Abstract

A slice of of the CMS calorimeter was tested at the H2 test beam area of CERN with different beams of energy ranging from 3 GeV to 300 GeV. Some of these data is for the hadron calorimeter prototype where every individual layers were readout independently. This enables study of longitudinal shower profile of electron, hadron and muon beams. This talk will cover the calibration procedure with electron beam. The longitudinal shower profile for electrons is studied and compared with predictions from GEANT4 simulation models.

1 Introduction

CMS calorimeter system[1] consists of two kinds of detectors - electromagnetic calorimeter (ECAL), a lead tungsten crystal calorimeter to detect and measure energy of electron and photon and hadron calorimeter (HCAL), a sampling calorimeter, to absorb and measure the energies hadrons.

The CMS Electromagnetic Calorimeter (ECAL[2]) consists of lead tungstate crystals which provide a good energy and position resolution for electrons and photons.

The CMS Hadron Calorimeter (HCAL[3]) consists of a barrel (HB) and an end cap (HE) detector. It uses plastic scintillator as the active material and a copper alloy (90% Cu and 10% Zn) as the absorbing material. The alloy has an interaction length of $\sim$ 15cm. Mechenically HB has a polygonal structure made by connecting 18 calorimeter wedges into half barrels. Each wedge subtends an angle of 20° in ϕ and extends in z by 4.3 meters from the CMS mid-plane. There are 17 active layers of scintillator trays. Layer 1 and layer 17 are 8 mm thick and the remaining layers are each 4 mm thick. One or two layers of scintillator trays, known as outer hadron (HO), each 10 mm thick, are added outside the magnet coil to sample the tail of the hadronic shower. The scintillator light is collected from the trays using wavelength shifting fibers and is transmitted to Hybrid Photo diodes (HPDs) using optical fibers. The HB has two different kinds of readout configuration, in one configuration the signals of individual layers are summed up (called as HB1 configuration) and in the other case we readout every individual layer separately (defined as HB2). Granularity of the readout is $\Delta\eta \times \Delta\phi = 0.087 \times 0.087$. The digitisation of the analog signal is done at the beam crossing frequency of 40 MHz by QIE chips (Charge(Q) Integration(I) range Encoding(E)).

2 The experimental setup of TB 2006

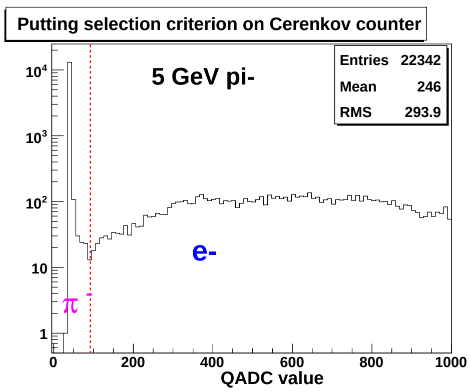
Test Beam 2006 used the real CMS ECAL and HCAL modules for the first time. The HCAL in test beam includes the barrel (HB), endcap (HE) and the outer hadron (HO). During testbeam 2006 incident particles with momenta varying from 1 GeV/c to 300 GeV/c are used. Very Low Energy (VLE) line provides 1 to 9 GeV/c π^-, π^+, e^- and e^+ with good rate, a few hundred/spill using a tertiary target (T22). At lower end of the range, particles are mostly electrons. There is a significant muon contamination as well. Particle ID is accomplished by time of flight counters (TOF), Cerenkov counters (CK) and muon veto counters.

High energy line covered a momentum range from 10 to 300 GeV/c for hadrons through secondary particle production. For electrons/ positrons, the range was 10 to 150 GeV/c.

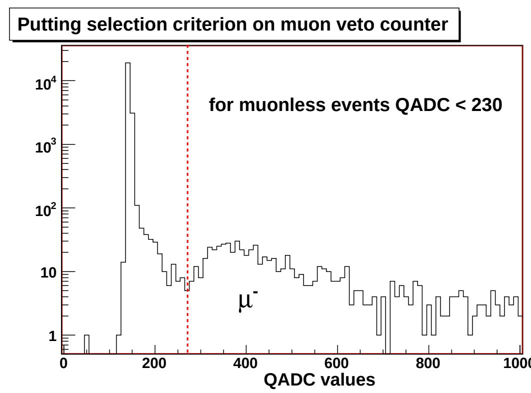
The new CMS software framework (CMSSW) was used for validating the data for the first time in this test beam experiment.

3 Longitudinal shower profiles

A particle loses all its energy in calorimeter through shower generation. In order to study this property, we examine the longitudinal shower profiles with electron beams at different energies in the hadron barrel without keeping the ECAL module in front of it. Electron beams at low energy have large contamination from pions and muons. We reduce these contaminations by using *muon Veto counters* and *Cerenkov counters*. The beams at different energies pass through these veto counters and the ADC counts of the counters are noted.



(a) Selection using Cerenkov counter



(b) Selection using Muon veto counter

Figure 1: Selection criteria

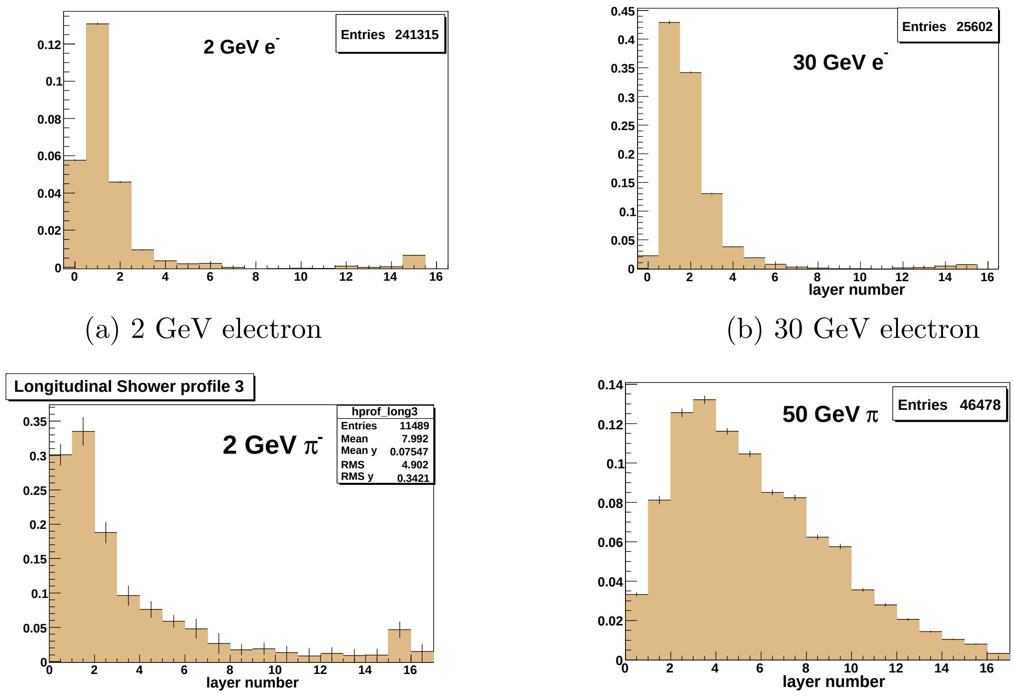
In Fig.1(a) the ADC distribution for an electron beam is shown. One notices a clear threshold at a QADC value of 100, above which we get electrons and below that we have pions. Fig.1(b) shows how to put a criterion on a muon veto counter to reduce the muon contamination from the beam.

The longitudinal shower profiles with electron beam with energies ranging from 2 GeV (VLE) to 300 GeV (HE) are studied using the HB2 alone configuration. The energy deposited in each layer is studied as a function of layer number: $1-17$. Fig.2(a) and 2(b) show the fraction of shower energy measured in each layer.

As in the very low energy regime the pions are mostly contaminated with electron (the contamination goes up to more than 70%). We use the pion runs with appropriate selection criteria (as shown in Fig.1(a)) to select events due to electron. For longitudinal shower profile of higher energies electron beams are used.

It is observed that the profile has a rising and a sharply falling part which shows that the electron beam begins showering already in the calorimeters and it deposits most of its energy in the very first few layers. In contrast a high energy electron beam continues to the further layers depositing its energy as the shower development continues in the latter layers.

The electron beam profile falls sharply as opposed to pion beam where the longitudinal shower profiles would have a gradual fall (as shown in Fig.2(c) and 2(d)). It is also worth noticing that



(a) 2 GeV electron

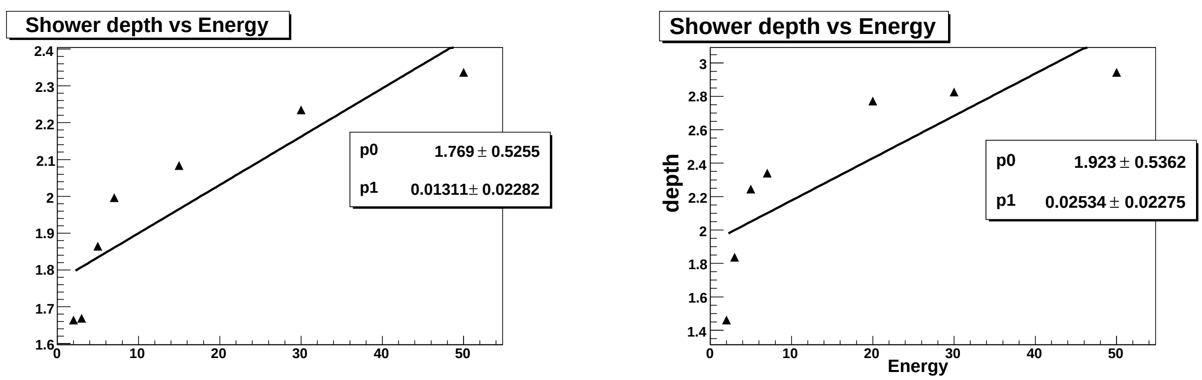
(b) 30 GeV electron

(c) 2 GeV pion

(d) 200 GeV pion

Figure 2: Longitudinal Shower profiles of electrons and pions at different energies

the average shower depth increases logarithmically with energy for both electrons and pions (refer Fig.3), shower depth seen to be more in case of pions.



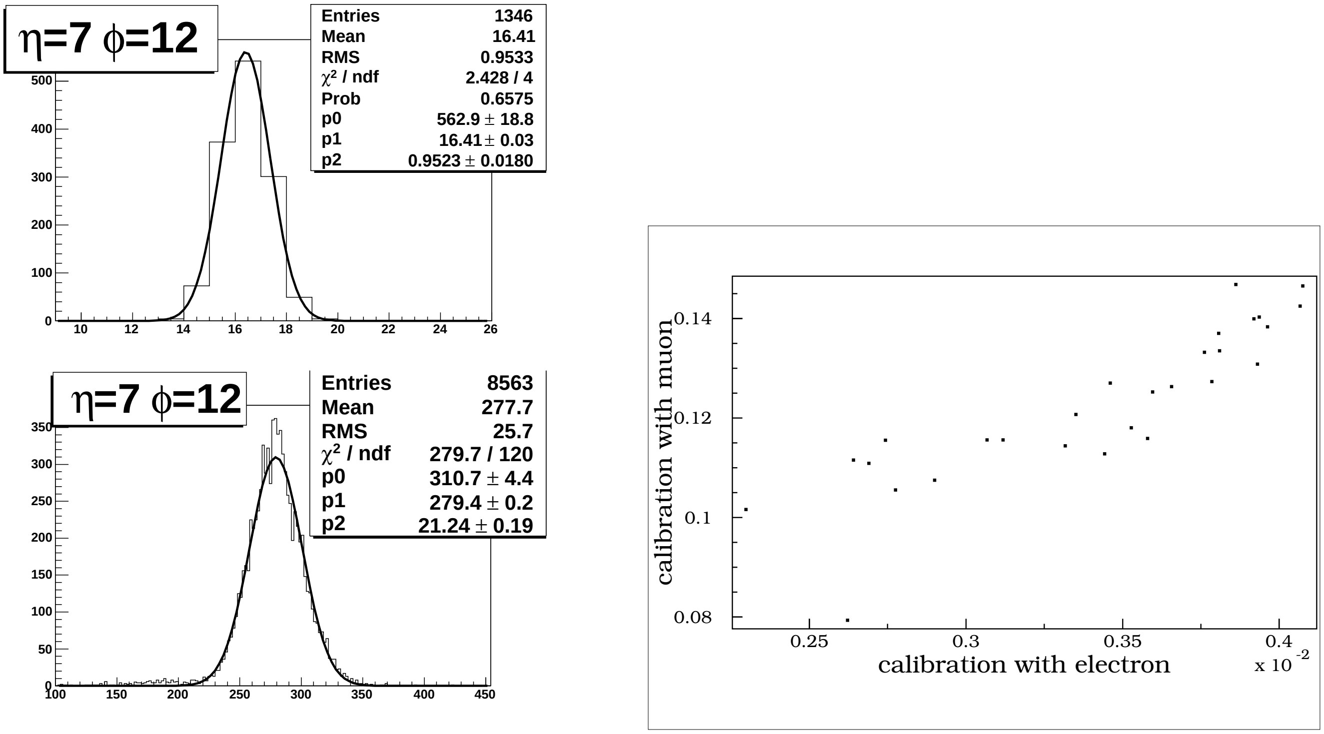
(a) for electrons

(b) for pions

Figure 3: Shower depth as a function of incident beam energy for electrons

4 Calibration with electron beam

Using the set of data taken with 50 GeV electron beam in hadron barrel (HB1, to be precise) the calibration constants for the entire HB1 is found out. The procedure followed here was first to plot the pedestal events (all kinds of pedestal trigger events) and signal events (beam trigger events with the selection criteria for selecting out muons and pions using beam counters) separately. The pedestal was fitted with a Gaussian function. The signal function was fitted again with a Gaussian



(a) Calibration procedure (b) Correlation plot

Figure 4: Calibration constants as obtained from plots of the pedestal and the signal with electron data and the correlation between the calibration constants from electrons and those from muons.

having the width fixed from pedestal data (refer Fig.4(a)). The calibration constant was found out by taking the inverse of the mean of the fitted function on the signal. The scatter plot in Fig.4(b) shows the correlation between the calibration constants obtained from electron data with that obtained from muon data.

5 Conclusion and Outlook

We have studied electron runs at various energies from the test beam 2006. The longitudinal shower profiles from the data reflect a good response of CMS Hadron Calorimeter to electron beams. The calibration constants for the hadron calorimeter obtained with the electrons seem to have a good correlation with those obtained from the muons.

References

[1] CMS Collaboration, "The Compact Muon Solenoid - Technical Proposal", CERN/LHCC 94-38, 1994.

[2] CMS Collaboration, "The Electromagnetic Calorimeter Technical Design Report", CERN/LHCC 97-033, 1997.

[3] The Hadron Calorimeter Project, Technical Design Report, CERN/LHCC 97-31, June, 1997.